# Earwig Management Tool: a practical software application to predict and optimize the development of earwig populations in pip fruit orchards

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## Abstract

*Earwigs* (Forficula auricularia L.) *are omnivorous insects that are considered as important beneficial insects in pip fruit orchards. They are, if abundant, capable of maintaining several pest species below economic thresholds. However, earwig abundance in orchards can greatly vary from location to location, and showed to be highly dependent on orchard management. Thorough knowledge of earwig population dynamics in the field is crucial in order to avoid negative effects of necessary orchard management, such as spray applications and soil tillage. A precise timing of these interventions taking into account the presence of vulnerable life stages of the earwig life cycle will enhance biocontrol in pip fruit orchards. To this end, we developed a day degree model capable of predicting the phenology of local earwig populations. This phenological model was integrated in a practical software application, called 'Earwig Management Tool', together with data concerning earwig sensitivities to distinct orchard management actions. Consultation of this user-friendly software enables fruit growers to organize their orchard management with respect for optimal development of earwig populations.*

**Keywords:** earwig, *Forficula auricularia* L.*,* day degree model, biocontrol, pip fruit orchards, advice software tool

## Introduction

The European earwig *Forficula auricularia* L., an important predator of several pests in pip fruit, e.g. woolly apple aphid *Eriosoma lanigerum* Hausmann (Mueller *et al*, 1988; Nicholas *et al*., 2005) and pear sucker *Cacopsylla* spp. (Lenfant *et al*., 1994; Phillips, 1981), has an univoltine life cycle including a leaf dwelling period from end of May until end of October (Gobin *et al*., 2006). During their life cycle, earwigs move in different strata of the orchards (soil, ground surface, tree), each with specific risks of side effects. Females lay eggs in an underground nest and provide broodcare to eggs and the first nymph stage. When maternal care ends, the nymphs live on the ground surface. These nymphs will disperse shortly thereafter and move into the trees. Considering earwig's population dynamics there actually exist two 'population types' in the field. Single-brood populations have one reproductive cycle a year and lay eggs before winter (November to December) (Moerkens *et al*., 2009). They are characterized by a prolonged maternal care by the female. Double-brood populations have two reproductive cycles a year and lay eggs after winter (January to February) and in summer (June to July) (Moerkens *et al*., 2009). In this second strategy, females abandon their young after the first moult, disperse and start a second nest. The free-foraging phase of nymphs starts from the third-instar stage in single-brood populations and second-instar stage in double-brood populations. The arboreal phase starts from the fourth-instar stage in single-brood populations and from the third-instar stage in double-brood populations (Moerkens *et al*., 2009).

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Their univoltine life cycle makes earwigs vulnerable to orchard management interventions and a single disastrous event has long-lasting repercussions (Gobin *et al.*, 2006). An important mortality factor is the application of soil tillage in organic orchards. This is carried out for weed control, which is important for increasing nutrient uptake by the trees. It is often applied in autumn and/or in spring, when adult earwigs hibernate in their underground nests. Obviously, this application can cause nest destruction, hereby exposing the hibernating earwig to cold, deadly surface temperatures or loosing already laid eggs. In addition, the wrong use of spray applications in spring and summer can lead to severe reductions in earwig densities with long-term consequences (Peusens *et al.*, 2010). Timing of soil tillage and spray applications is in practise very hard for pip fruit growers and often not realistic. To this end, we have developed a user-friendly software tool, based on an existing day degree model (Moerkens *et al*. 2011a) and detailed knowledge about orchard management causes of earwig mortality.

## Material and Methods

### Phenological day degree model

The phenological day degree model for earwigs was developed as described previously (Moerkens *et al.*, 2011b), taking into account the existence of single-brood and double-brood populations. It consists of two components: (i) the prediction of the first appearance dates of all earwig's life stages from the nesting and free-foraging phase and (ii) the prediction of the variation in development time of earwig life stages in the trees. To calculate the lower and maximum developmental temperature thresholds and sum of day degrees we used development rates expressed as the reciprocation of development time between two developmental life stages (1/number of days). This was implemented in the model of Briére *et al*. (1999), which enables the simultaneous fitting of a nonlinear response to temperature and assessment of the lower developmental temperature threshold and the maximum developmental threshold. Detailed information about the development rates of earwigs in relation to many different temperatures; which were acquired by means of breeding experiments and published data, was used for the model. Development rates of the fastest individual to hatch and moult. were used to fit to the nonlinear model and parameters were estimated with the NLIN procedure of sas, version 9.1 (SAS Institute, 2002). This procedure performs a univariate nonlinear regression using the least squares method. Residuals were checked for normality. The phenological day degree model was programmed in sas (SAS Institute, 2002). This model was programmed with discrete time intervals of 1 day. Simulations started at the time of overwintering females in September and lasted until December of the next year. Detailed temperature data relevant for the nesting and free-foraging phase were used as input into the model.

### Determination of side effects of sprayings

Adult earwigs *Forficula auricularia* L. were collected in several orchards (apple and pear, integrated and organic) during the summer using cardboard shelters placed in trees. After sampling, test organisms were kept under controlled environmental conditions (temperature 16°C, humidity 60% RH, photoperiod 12/12 h) in separate plastic containers provided with water and food (crushed cat food) ad libitum. Prior to each test an equal number (50 % male/50 % female) of each population was chosen at random and mixed together to pool the test individuals.

Based upon the standard testing scheme of pesticides selectivity to non-target arthropods, residual laboratory tests on inert substrate and on natural substrate were conducted according to the recommended methods (Candolfi *et al.*, 2000) with minor modifications.

We executed different laboratory tests in which spraying products were either directly sprayed on earwigs present on potted apple seedlings, or indirectly contaminated by residues on leaves or treated prey (woolly apple aphids, *Eriosoma lanigerum*). However, only the data generated by the indirect contact method in which earwigs were exposed to at beforehand treated leaves were used to feed the advice generation of the software tool. In these laboratory tests, exposure of residue was carried out in a test unit that consisted of a small petri dish (diameter 35mm). Test products were applied directly on the petri dish (initial toxicity on inert substrate) or on detached bean leaf disc mounted upside down on wet cotton wool in a petri dish (extended lab test on natural substrate) and closed with a ventilated lid. One hour after application when the residue had dried, earwigs were confined individually to a test unit for 24 hours after which the earwig was transferred to an untreated petri dish together with food and water. All compounds were sprayed using a handheld pressure sprayer until run-off under natural circumstances. Per test item 12 earwigs (6 males and 6 females) were tested. All test units and petri dishes were stored in an environmentally controlled growth chamber (temperature 14°C, relative humidity 60 % RH, photoperiod 12/12 h/h light/dark) during the entire test period. The condition of the earwigs was assessed and recorded as living, moribund (on their back, unable to right themselves up) or dead at 24, 48, 72, 96, 144 and 168 hours after treatment. Mortality (% moribund and dead earwigs) was calculated and corrected according to Abbott (1925) and rated according to the IOBC-classification for lab trials: 1 = harmless (<30% effect), 2 = slightly harmful (30-79% effect), 3 = moderately harmful (80-99% effect), 4 = harmful (>99% effect). All statistical analyses were performed using the Unistat Statistical Package, version 5.6 (Unistat Ltd. 2009, London, England). A non-parametric randomised block test of Friedman (two-way Anova) was conducted, in which the original data are ranked within each block. Multiple comparisons between treatments are based on ranking sums and differences are determined by t-distribution (Honestly Significant Difference)($p<0.05$).

Programming software Earwig Management Tool

The software tool was programmed in Visual Basic. The program automatically makes a connection with a mysql database on a secured webpage. In this mysql database temperature data (minimum and maximum temperature, air and soil (-5 cm)) are daily updated.

## Results and discussion

The Earwig Management software tool is an integration of the day degree model for earwigs with orchard management recommendations. The program has a user friendly graphical interface (Figure 1), easy-to-use options, and one-click features. The software can be downloaded at www.pcfruit.be, and installed on any personal computer with a windows operating system. While running the program, a connection to the internet is required for updating the temperature data in order to generate accurate predictions of the actual earwig phenology. In addition, a database with known side effects of soil tillage and spraying applications on the different life stages of earwigs is integrated in the system. The output gives the current status of the earwig population and management recommendations for activities critical for their survival. Hence, by consultation of this user-friendly software fruit growers can predict the earwig development in the field at any time, and organize the timing of orchard management actions taking into account the presence of (vulnerable) life stages of the earwig life cycle. Doing so, negative effects of specific orchard management actions, such as badly timed spray applications and soil tillage, can be avoided.

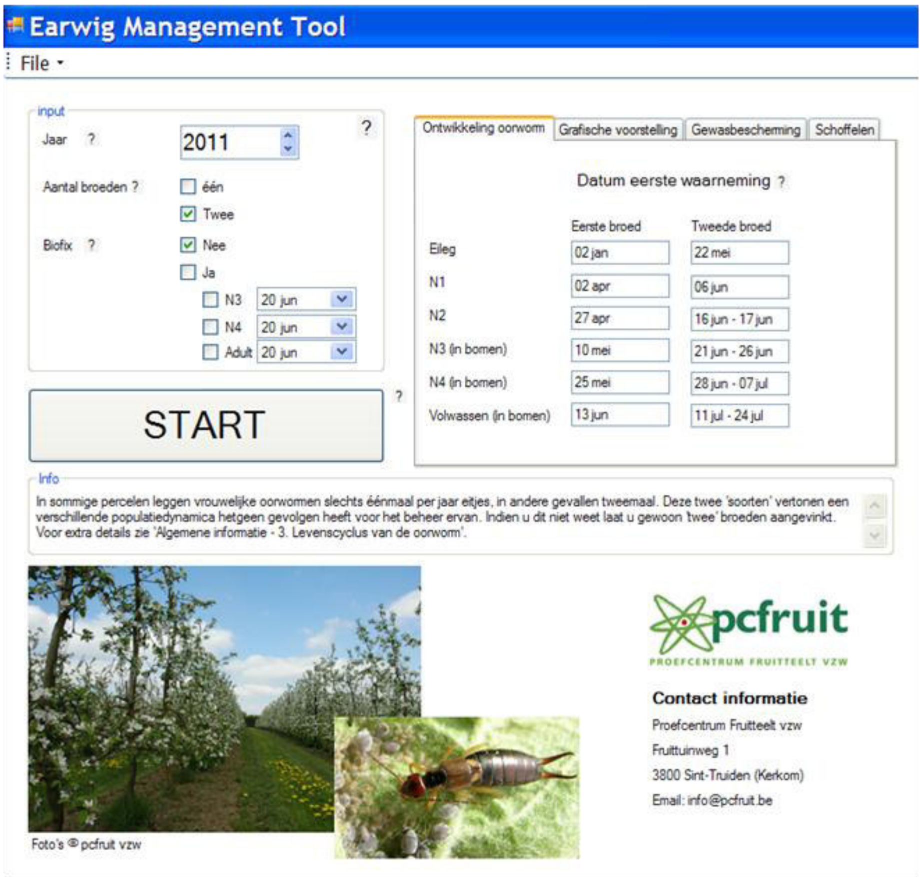


Figure 1: Graphical interface of the Earwig Management Tool program

## Acknowledgements

EFRO (Cleantech project 453) is gratefully acknowledged for funding this work. Also the Institute for the Promotion of Innovation by Science and Technology of Flanders (IWT) supported part of this work financially by an agricultural research grant 040667. We thank Tom Thys for invaluable assistance in data collection.

## References

Abbott, W.S. (1925). A method for computing the effectiveness of an insecticide. *Journal of Economic Entomology* **18**: 265-267.

Briére, J.F., Pracros, P., LeRoux, A.Y. & Pierre, J.S. (1999). A novel model of temperature dependent development for arthropods. *Environmental Entomology* **27**: 94–101.

Candolfi, M.P., S. Blümel, R. Forster, F.M. Bakker, C. Grimm, S.A. Hassan, U. Heimbach, M.A. Mead-Briggs, B. Reber, R. Schmuck, & Vogt, H. (2000). Guidelines to evaluate side-effects of plant protection products to non-target arthropods. IOBC/WPRS, Gent.

Gobin, B., Marien, A., Davis, S. & Leirs, H. (2006). Enhancing earwig populations in Belgian orchards. *Communications in Agricultural and Applied Biological Sciences* **71**: 269–273.

Lenfant, C., Lyoussoufi, A., Chen, X., Faivre d'Arcier, F.& Sauphanor B. (1994). Potentialités prédatrices de *Forficula auricularia* sur le psylle du poirier Cacopsylla pyri. *Entomologia Experimentalis et Applicata* **73**: 51-60.

Moerkens, R., Leirs, H., Peusens, G., Beliën, T. & Gobin, B. (2011a). Natural and human causes of earwig mortality during winter: temperature, parasitoids and soil tillage. *Journal of Applied Entomology*. doi: 10.1111/j.1439-0418.2011.01676.x

Moerkens, R., Leirs, H., Peusens, G. & Gobin, B. (2009) Are populations of European earwigs, *Forficula auricularia*, density dependent? *Entomologia Experimentalis et Applicata* **130**, 198–206.

Moerkens, R., Gobin, B., Peusens, G., Helsen, H., Hilton, R., Dib, H., Suckling, D.M. & Leirs, H. (2011b). Optimizing biocontrol using phenological day degree models: the European earwig in pipfruit orchards. *Agricultural and Forest Entomology* **13**: 301-312.

Mueller, T. F., Blommers, L. H. M. & Mols, P. J. M. (1988). Earwig (*Forficula auricularia*) predation on the woolly apple aphid, *Eriosoma lanigerum*. *Entomologia Experimentalis et Applicata* **47**: 145-152.

Nicholas, A. H., Spooner-Hart, R. N. & Vickers, R.A. (2005). Abundance and natural control of the woolly aphid *Eriosoma lanigerum* in an Australian apple orchard IPM program. *BioControl* **50**: 271-291.

Peusens, G., Beliën, T. & Gobin, B. (2010). Comparing different test methods for evaluating lethal side effects of some insecticides on the European earwig *Forficula auricularia* L. *IOBC/WPRS Bull*. **55**: 95–100.

Phillips, M. L. (1981). The ecology of the common earwig *Forficula auricularia* in apple orchards. PhD Thesis, University of Bristol: 1-241.

SAS Institute (2002) SAS 9.1 for Windows. SAS Institute, Cary, North Carolina.